Modelling of Sustainable Solutions in a Rejuvenated Brownfield Site

Modélisation et techniques alternatives sur un site réhabilité

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RESUME

Le projet démontre l'utilisation de techniques alternatives pour minimaliser les risques d'inondation, sur un ancien site industriel réhabilité.

L'étude met en évidence comment la représentation de ces techniques peut être implémentée dans un modèle, pour assister les techniciens et ingénieurs dans le cadre de développement de solutions liées aux problèmes spécifiques au site.

ABSTRACT

The project seeks to promote the use of Sustainable Drainage Systems (SuDS) for flow conveyance, attenuation and flood risk reduction to maintain the existing hydrological regime in a brownfield site.

The study utilises the latest facilities for representing SuDS in a hydraulic model and shows how they can be assessed in conjunction with traditional sewerage structures to assist engineers in developing sustainable solutions to the hydraulic problems present on the site.

KEYWORDS

Integrated ; Modelling ; SUDs.

INTRODUCTION

The use of Sustainable Drainage Systems (SuDS) is becoming increasingly widespread. There is a need for integrated modelling to design the SuDS systems and assess their impact on the surrounding catchment. This paper details the hydraulic modelling of a rejuvenated brownfield site which includes a variety of SuDS. The paper demonstrates the impact of changing design parameters.

1 CATCHMENT DESCRIPTION

Telford Millennium Community (TMC) is one of seven Millennium Communities throughout England. TMC comprises 35 hectares of brown field land, north-west of Telford, in the heart of England. The site slopes fairly steeply from South West to North East, with a total fall across the site of about 12 m. The site currently consists of 15 Victorian terraced houses and has been left fallow for many years. There are areas within the site that have subsequently become important habitats for wildlife. A local watercourse that passes through the site also requires protection against the threat of contaminated inflows, in addition to flood risk protection from surface water runoff inundation.

The figure below shows an outline of the catchment with the relevant SUDs features indicated.

The proposed TMC development comprises mainly housing, with some live/work units, a school, some small offices and retail and leisure services. The development also incorporates habitats for a variety of wildlife including a resident population of Great Crested Newts, a protected species. The TMC project seeks to promote the use of SuDS for flow conveyance, attenuation, flood risk reduction, passive treatment to improve water quality and to maintain the existing hydrological regime to protect the Great Crested Newt population.

The catchment is served by separate storm and foul systems. The storm system is divided into a system to convey flow directly to the newt ponds and a primary system to provide both flood protection and to control the existing hydrological regimes through the northern wildlife corridor. The SuDS features which will be incorporated into the drainage system are:

- Two grassed swales
- A gravel trench, sited at the bottom of a grassed ditch
- A pond
- A cascade, serving the newt pond system

The site includes redundant mine workings and colliery spoils and there is therefore potential for the inflow of contaminants. A 1.2mm Flexible Polypropylene Alloy Geomembrane is proposed to protect the storm water systems and ultimately the wildlife from pollution. Unfortunately this impermeable barrier limits the effectiveness of many SuDS, this will be discussed later.

2 PROJECT DESCRIPTION

The project comprised the design of the hydraulically independent storm systems serving the newt ponds and also the spine road and homezone areas. The reason that two systems are required is that runoff from highways and other hard standing areas may contain pollutants such as heavy metals (zinc, copper, cadmium) and chlorides. These pollutants are harmful to newt populations and required controlling from entering their habitat. Therefore, to reduce the effects of contamination, the newt ponds will be mainly served by undeveloped green areas, although to maintain the existing hydrological regime there will be the need to discharge some roof and hard standing areas.

The design criteria, including that of the SuDS were specified to meet the following three surface water management objectives.

- Reduce Flood Risk in accordance with PPG25
- Ensure the existing sensitive ecological habitats are maintained
- Provide a cost effective drainage solution that mitigates future cost and safety

The project was completed by first predicting the existing hydrological performance of the undeveloped catchment. This was required to provide a benchmark against which development could be assessed.

Both storm systems were then modelled using the InfoWorks CS software package. InfoWorks CS was chosen because it has the ability to represent the hydraulic aspects of SuDS structures and to allow them to dynamically interact with more familiar hydraulic drainage structures including pipes, channels and manholes. The model is used to compare the developed catchment against the predicted existing performance to determine whether the design objectives have been met. Representation of the primary system, including the SuDS is presented in section 3.1.

2.1 The primary drainage system

The primary drainage system flows west to east across the catchment. At the head of this system there is an area of about 1.3 hectares comprising a school playing field. This is represented in InfoWorks CS using the groundwater infiltration module. The system then receives flow from the homezone areas, which are represented using a fixed percentage runoff contribution.

The underlying principle in the design of this system was that the existing hydrological conditions in the undeveloped site should not be altered. A gravel trench, two swales and a pond used to provide the necessary attenuation and storage of flow. These are discussed in the sections below.

2.1.1 Gravel trench

A trench filled with gravel was required to attenuate the flows leaving the school playing field. This SuDS was chosen is preference to other forms of flow storage and attenuation as it was not considered desirable to have an open body of water within school grounds.

The longevity of such a trench is enhanced through the incorporation of a filter strip, gully or sump to remove excessive solids at the inflow. These reduce the likelihood of blockages of the interstices. These structures facilitate the storage and filtering of water on route from the source to the discharge point. Many similar structures include the ability to loose flows to the surrounding soil through infiltration. However this was not possible in this catchment due to the contaminated land.

The gravel trench used in this project is 500 mm deep and 176 m long, with a gradient of 0.00114. It sits at the bottom of a drainage ditch. When the capacity of the gravel is exceeded, the flow can pass over the gravel whilst being contained within the ditch. The ditch has a side slope of 1:4 which is required for safety and so that the grass can be easily cut

There are two key aspects of InfoWorks CS which allow the representation of such a structure. The first is that flows through the gravel trench will have different characteristics to the flows in the ditch, once the gravel is surcharged. InfoWorks CS allows different numerical solutions to be specified to represent these different flow regimes. Flows in the gravel are represented using Darcy flows (Shaw 1994) whereas flows in the open ditch use the standard full solution of the St Vennant equations (Yen 1973.) The choice of which solution model to use is simply made in InfoWorks CS from the conduit definition tab in the conduit properties.

The second aspect is that in traditional sewage system all flows will enter at the top (of the pipe.) However in a gravel trench, the flows will enter from the sides and therefore increase uniformerly along the length of the trench. In InfoWorks CS, subcatchments can now be specified as draining to a link, using a tick box in the sub-catchment properties. If this is specified then the runoff contribution is equally divided between the computational nodes which are equally spaced along all conduits.

Flow through a gravel trench is represented using the 4-point Preissmann finite difference scheme, where the two governing equations are:

1. Conservation of mass the same as for full (St Vennant) flow, but accounting for the porosity of the flow medium.
2. Darcy equation for flow rate, as recommended by, amongst others, Wilson (2004)

There are three key elements of design with which the numerical modelling can assist.

- How big the trench should be
- What Darcy value should be specified
- What is the impact of the structure downstream

The performance of the trench could be improved if there was the ability to loose flow via infiltration into the surrounding soil. This can be represented by the model, but cannot occur in practice due to the presence of contaminated soil.

2.1.2 Swales

A swale is an open grassed ditch used to convey flow. In this project two main swales are used. Each swale has a side slope of 1:4, which was chosen for issues of safety and to allow the easier maintenance. Each has a 'check dam' and orifice immediately downstream of it to attenuate flows. The swales are therefore effectively acting as on-line storage. The size of the dams and orifices were designed so that there would be no overtopping during a 1:100 year event and the existing peak pass forward flows from the undeveloped site would not be exceeded.

The velocity of the flows in swales will in the case of TMC allow the swale to act as a treatment facility by permitting the deposition of suspended materials; however siltation is considered a major issue in the main swales due to the treatment the flows previously received when passing through the gravel trenches, cascades and ponds..

A swale is another example of where the contribution of a sub-catchment to a link, rather than a node is useful. This can be used in a variety of situations, but is particularly useful in representing a road, car park or any other hard standing area which has a swale or gravel trench running the length of it. As water runs off the area, it will cause the flows in the swale to uniformly increase.

The critical factor when designing swales was to ensure that flows within the channel remain sub critical at all times. Sub critical flows reduce the effects of scour on the channel and allow hydraulic controls to be applied at the location such as check dams. InfoWorks CS could be used to check flow conditions for a variety of storms.

2.1.3 Ponds

There are three aspects of a pond which are not seen in most traditional sewerage schemes, but do require numerical representation.

- The runoff characteristics will vary depending on the water level. When the pond level is low, much of the surrounding area is likely to be vegetated, effectively permeable area with a low proportion of runoff. As the pond fills this area becomes submerged. The surface of the pond will act as a highly impermeable area, with 100% runoff and no attenuation through routing. This means that the contribution to the pond will change due to antecedent conditions.
- There is the potential for the pond to be emptied due to evaporation (included in the rainfall event characteristics.)
- The pond can also be emptied due to an infiltration loss to the surrounding soil.

3 RESULTS

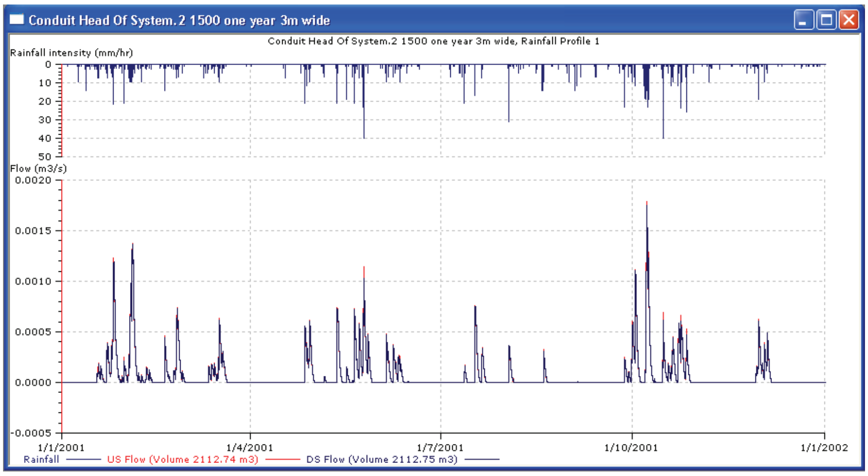
Once a model has been created, using the processes outlined in Chapter 3, a variety of scenarios can be quickly and easily tested. The testing takes two forms, analysing the catchment during severe storms events, such as those with a return period of 1:100 years and also during more frequent events.

This paper focuses on the analysis of the more frequent events. Issues such as how often the gravel trench becomes inundated, a potential health and safety issue in a school playing field, and how often the Newt ponds and likely to dry up can be investigated.

The model was simulated with a continuous rainfall event lasting for one year.

The graph below provides an example of the type of analysis which can be easily undertaken once a hydraulic model of the catchment has been constructed.

The figure below shows the overflow from the gravel channel.

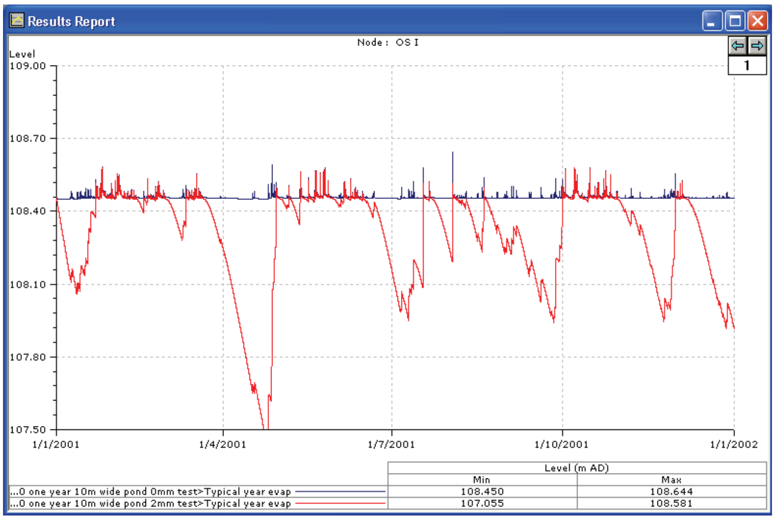


InfoWorks CS includes a statistical analysis tool which allows the number of failures (say the number of times the gravel trench overflows) and the total volume and duration of the failures (overflows.)

The table below presents the results of analysis into varying trench widths.

Trench Width (m)	Peak flow (l/s)	Volume (m^3)	Duration (days)
0.5	2.6	3286	170.5
3.0	1.7	2113	101.1
10.0	1.1	411	15.2

Further analysis was conducted on the Newt pond, to determine the maximum loss rate into the soil which could be sustained without the ponds completely emptying during the year. The graph below shows that with a loss rate of 2mm/hr the pond will completely empty once in the year.



4 CONCLUSIONS

Hydraulic modelling of sewerage systems and surface water management projects is not new, it is a tried and trusted way of dynamically solving often complex engineering problems. However, with the ever increasing development of SuDS, modelling has to keep pace so that the same levels of confidence and understanding can be applied to new and innovate drainage systems.

Modelling of the brownfield redevelopment at TMC has allowed the flexibility of SuDS to be demonstrated. It has shown that an integrated model of SUDs features and more traditional sewerage infrastructure can allow an holistic approach to analysis of the catchment to be undertaken. This is vital as the performance of one feature impacts on others around it. It has also shown that analysis of severe events and annual performance is important when trying to establish whether a proposed design is acceptable.

The model showed how the SuDS schemes worked well together. The high attenuation provided by the gravel trench meant that the pond received a relatively constant inflow, meaning that it would not run dry, even during long periods of dry weather.